NASA-CR-193499

p. 4

Determination of the Stability and Control Derivatives of the F/A-18 HARV from Flight Data Using the Maximum Likelihood Method

NASA Grant # NCC 2-759

Final Report
(November 1992 - May 1993)

NASA Technical Contact: Albion H. Bowers
NASA Dryden Flight
Research Facility

Authors:
Principal Investigator: Marcello R. Napolitano
Graduate Student: Joelle M. Spagnuolo

Department of Mechanical and Aerospace Engineering
West Virginia University
Morgantown, West Virginia 26505

This document reports on the progress of the research conducted for the NASA-Ames Cooperative Agreement No. NCC 2-759. The principal investigator is Marcello R. Napolitano and the graduate student is Joelle M. Spagnuolo both of West Virginia University. The NASA technical officer for this agreement is Albion H. Bowers, NASA Dryden Flight Research Facility. The research being conducted is related to the determination of the stability and control derivatives of the F/A-18 HARV from flight data using the Maximum Likelihood Technique.

The parameter estimation program, pEst, is being used so that the nonlinearities in the dynamic equations of motion can be properly modeled. A preliminary mathematical model of the HARV has been implemented into pEst. This model accounts for the additional control surfaces of the HARV including the thrust vectoring control system (TVCS) which generates thrust forces in the *x*, *y*, and *z* planes as follows:

$$thrust(x) = -cadpvdyv * \cos(\delta_{pv})\cos(\delta_{yv}) * measured\ thrust\ force$$

$$thrust(y) = -cydyv * \sin(\delta_{yv})\cos(\delta_{pv}) * measured\ thrust\ force$$

$$thrust(z) = -cnormdpv * \sin(\delta_{pv})\cos(\delta_{yv}) * measured\ thrust\ force$$

where δ_{yv} = yaw vane deflection
δ_{pv} = pitch vane deflection
$\delta v_{1,2..6}$ = deflection of individual vane 1,2,3,4,5 or 6
cadpvdyv = axial force due to combined δ_{pv} and δ_{yv}
cydyv = side force due to yaw vane deflection
cnormdpv = normal force due to pitch vane deflection

The state equations incorporate the above modifications as follows:

$$\dot{V} = \frac{1}{m}[-D\cos\beta + Y\sin\beta + thrust(x)\cos\alpha\cos\beta + thrust(y)\sin\beta + thrust(z)\sin\alpha$$

$$-mg(\cos\alpha\cos\beta\sin\theta-\sin\beta\sin\phi\cos\theta-\sin\alpha\cos\beta\cos\phi\cos\theta)]$$

$$\dot{\alpha}=\frac{1}{Vm\cos\beta}[-L+thrust(z)\cos\alpha-thrust(x)\sin\alpha+mg(\cos\alpha\cos\phi\cos\theta$$

$$+\sin\alpha\sin\theta)]+q-\tan\beta(p\cos\alpha+r\sin\alpha)$$

$$\dot{\beta}=\frac{1}{mV}[D\sin\beta+Y\cos\beta-thrust(x)\cos\alpha\sin\beta+thrust(y)\cos\beta-thrust(z)\sin$$

$$+mg(\cos\alpha\sin\beta\sin\theta+\cos\beta\sin\phi\cos\theta-\sin\alpha\sin\beta\cos\phi\cos\theta)]+p\sin\alpha-r\cos\alpha$$

where D = total Drag, (lb)
Y = total Sideforce, (lb)
p = roll rate, (rad/sec)
q = pitch rate, (rad/sec)
r = yaw rate, (rad/sec)
α = angle of attack, (rad)
β = angle of sideslip, (rad)
θ = pitch angle, (rad)
ϕ = bank angle, (rad)

The mathematical model with the previous modifications has been used to analyze fight data at small angles of attack; the results from pEst were encouraging. However, when higher angles of attack were being investigated, some problems were evident with the model especially for the lateral directional case. Further investigation of the model and analysis of the data at higher angles of attack continues.

References

1. Maine, R.E., and Iliff, K.W., "Application of Parameter Estimation to Aircraft Stability and Control -The Output Error Approach", NASA RP-1168, June 1986.

2. Duke, E.L., Antoniewicz, R.F., Krambeer, K.D., "Derivation of a Linear Aircraft Model", NASA RP-1207, August 1988.

3. NASA Symposium Report TN-D-7647, "Parameter Estimation Techniques and Application in Aircraft Flight Testing", Volume I,II, April 1974.

4. Bowers, A.H., Noffz, G.K., Grafton, S.B., Mason, M.L., and Peron, L.R., "Multiaxis Thrust Vectoring Using Axisymmetric Nozzles and Postexit Vanes on an F/A-18 Configuration Vehicle", April 1991.